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CALIBRATOR FOR UNDERWATER SOUND MEASURING SYSTEM, (U)

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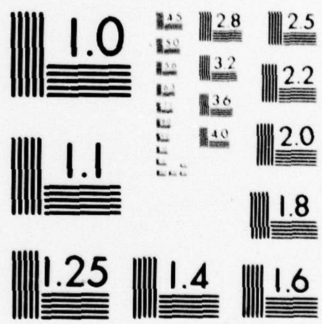
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NAVAL UNDERSEA RESEARCH and DEVELOPMENT CENTER

6 CALIBRATOR FOR UNDERWATER SOUND MEASURING SYSTEM

671191

By

10 John L. Leonard
Listening Division

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ADMINISTRATIVE STATEMENT

This work was performed by the Listening Division of the Sonar Technology Department under NAVSHIPS Problem SF11-552-003, Task 08119, "Low Frequency Ambient Sea Noise." The information herein is supplemental to that in NUWC Report TP-25, "A Portable General Purpose Underwater Sound Measuring System." It is published as a Technical Note at this time to make it available in a timely manner to all recipients of TP-25.

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ABSTRACT

This note describes an instrument for calibrating an underwater sound measurement and recording system. Detailed instructions are given for its construction and calibration. A separate section on "operation" supplies the needs of those concerned only with its use.

The instrument provides means of generating three kinds of signals, one KHz sine wave, "white" noise (spectrally flat), and "pink" noise (minus 3 dB per octave slope). Any one of these can be selected and injected into an external circuit such as the calibration circuit of a hydrophone. Means are provided for accurately controlling the level of these calibrate signals to a definite predetermined value. Provision is also made for the use of both external calibrating signals and external monitoring.

SUMMARY

The purpose, general theory, and application of an instrument for calibrating underwater sound measurement systems are described. Such a system would typically consist of a hydrophone, a five conductor cable, the calibrator, an analyzer, and/or a recording device. The hydrophone would in general have within its case a preamplifier, and some sort of built-in system for injecting a calibration signal just "after" the transducing element, and "ahead" of the amplifier. Thus, calibration includes everything in the system except the acoustic transducing element, which must be separately calibrated using an acoustic system.

Detailed instructions are given for constructing a calibrator. These include functional block diagrams, panel layouts, schematics, and wiring diagrams. A step by step procedure is given for calibration.

One self-contained section is given on operation of the instrument for those people who have no interest in building or repair, but need to use the equipment.

A problem example is included in the Appendix which should be of considerable help to those who are unfamiliar with measurements of this type.

TABLE OF CONTENTS

Purpose.

The NUC Sonar Calibrator was designed and built to be used in conjunction with the General Radio 1558 Octave Band Analyzer, the 1564 third octave analyzer, or similar equipment, and a calibrated hydrophone, to obtain accurate absolute measures of sound pressure level from various sources in the sea. Essentially, it is an instrument that can be set and reset to produce a known current in an external calibration circuit. It is a component of a portable, general purpose underwater sound measuring system (Reference 1).

The intended use would include a crystal hydrophone of known sensitivity, a pre-amplifier mounted in the same case with the hydrophone, and then as much as 1000 ft. of five conductor shielded cable, the upper end terminated in a connector that plugs into the "Calibrator" (see figure 3). A second, three conductor, shielded, short cable, connects the calibrator to the General Radio Analyzer. A recording device may be used, taking its signal from the analyzer.

The "Calibrator" can be used without the analyzer by supplying a power source for the hydrophone pre-amplifier, and a wide range attenuator preceding some indicating or recording device.

Description and Construction

The "Calibrator" consists of five basic parts plus batteries and splash-proof case. These parts are, a one kilo Hertz sine wave oscillator, a "white noise" generator, a "pink noise" filter, a calibrate signal injection amplifier, and a monitor amplifier. It is suggested that the case should be made of non-magnetic material, solid on five sides, the sixth side, the lid, should have all

parts connected to it, and it fastened into the box with four thumb screws. These should be two small eye bolts mounted somewhere on the case for securing at sea. The batteries should be easily replaceable without removing any interior component and their plus and minus positions clearly marked. They must be strapped down or contained very securely.

Electronics in the case include five potentiometer adjustments (2 more on the oscillator), that must be readily available preferably from the outside by removing a slot cover. There is no objection to putting all seven controls inside if they are immediately available when the whole works is lifted from the case, and if this requires only thumb screws!

All connectors, controls, and a meter are mounted externally on one face of the case, which is designed to set with the controls either "up" or "forward." The general arrangement and function of the controls are shown in figure 4. The hydrophone cable connects to PI, and the short cable to the analyzer connects to P2. Hydrophone pre-amplifier power is obtained from the batteries in the analyzer through pin 2 of P2.

Figure 5 is a block diagram of the principal parts and their functional interconnections. Note that the entire circuit is "floating" with respect to "signal ground," and the chassis. The cable shield connects to Pin 6 and Pin 2 of P2, thus grounding the shield at the top when the cable is plugged into the calibrator. Otherwise, the shield is floating top and bottom. On all figures the letter "C" with each variable control resistor shows its clockwise position.

Figure 6 gives schematic details of the built-in monitoring system. The intention is that whenever a true RMS current either "sine," "white" or "pink"

flows in an external calibrating circuit connected to Pins 4 and 5 of P1, figure 5, the meter will indicate at a fixed point or fiducial value. Thus the meter does not measure current or voltage in the usual sense, but simply becomes an indicator, at one point, that input conditions are duplicated. This one point is an arbitrary choice, and on this meter, in this model, was chosen to be "4" on the meter scale.

Diodes D_1, D_2, and the two 100μF condensors Figure 6 perform voltage doubling and rectification of the AC output from the amplifier. The resulting DC drives the meter. Since it is impractical to make a simple instrument respond equally to signals as different as sine waves and "white" noise, a three branch network, selectable by switch S5F, compensates for the three different signals used. Meter set adjustment R_6 permits the meter to be set at an arbitrary fiducial position. Diode D3 is used to protect the meter from overloads. The value of 560 ohms, for R3, and the 0.18V shown are nominal only. The diode should be operated on the knee of its current-voltage curve, and the proper point is critical to about $\pm$ 0.01 volts.

Adjustment for proper operation of the meter protecting Diode D3, can be accomplished as follows: Set switch S1, figure 4, to "external cal"; turn function switch to sine, inject a 1 KH sine wave into P7 and P8 (P8 the low side); connect an external monitoring voltmeter to P8 and P9. Adjust the input signal until the external monitoring meter reads 0.051V. If calibration (see "Adjustments and Calibration") has already been done, the meter in the "Calibrator" will read "4". Increase the input signal to 0.08V. The instrument meter should read "5" (full scale). At an input of about 0.13 to 0.15V the meter

should pin. If these latter conditions are not met select a different diode, and or vary the size of R3. This is all necessary because of variability in resistors and diodes from one unit to another.

Details for the Calibrate Signal "Injection Amplifier":J4 are given in figure 7. This amplifier drives one of the three selected calibration signals through the external calibration circuit connected to pins 4 and 5 of connector P1, figure 5. It will drive one milliamp RMS through an external impedance of Zero to 300 ohms. Its frequency response is ± 0.2 dB from 9 Hz to 100 KHz.

Figure 8 gives schematic details of the one kilo hertz sine wave oscillator together with instructions for initial adjustment at time of construction. Final adjustments cannot be properly made until after complete assembly. After construction and assembly are complete, short pins 4 and 5 of P1, figure 5, connect an oscilloscope and voltmeter to the "external monitor" (P8 and P9), set the rotary function switch to "sine" (position 3 in clockwise direction), "center" pot R2, and turn the amplitude pot (R8) for maximum output. The wave form will be greatly distorted at best. Slowly decrease the amplitude until an acceptable sine wave is produced. For greatest stability of the oscillator, use the largest amplitude that produces an acceptable wave form. A distortion of less than 2 or 3 percent should be easy to obtain. Next adjust the "level set" control on the front panel until the monitoring meter reads 0.051 volts. Adjust the frequency control pot (R7) to obtain 1000 hertz on the scope (with Lissajou figures or a counter), reset R8 for the same 0.051 V output on the meter. Do not change the "Level Set." Rest R7 for 1000 hertz. Repeat as required. No further attention will be needed to these two adjustments.

Power for the calibrator itself is obtained from two sets of batteries as shown in figure 9. One set, a 12 to 15 volt center grounded battery, the other 22.5 volt battery*. This is a highly undesirable situation that came about because at the time of design no integrated circuits were available that worked at 22 volts, and no white noise generator could be had that used 6 or 12 volts. The two diodes are used for protection only, in the event that polarity of the batteries should become reversed. Use a 15 ma load when testing batteries for minimum acceptable voltage.

The rotary "function switch," S5, shown in figure 4, consists internally of a 6 deck, 5 position, detented structure. Wiring details are given in figure 10. Position "1" is full counter clockwise, and is the "off" position where nothing is functioning. Moving in the clockwise direction, position "2" marked "operate", makes power through S2 available, to the hydrophone preamplifier. All calibration functions are inoperative. Power to the preamplifier remains available in positions 3,4, and 5. In position "3" the calibrator power is turned on, energizing the 1 KHz sine wave oscillator, the calibrate signal injection amplifier, and the monitoring amplifier and meter. Calibrator power remains on here and in positions 4 and 5. In position "4" the white noise generator is turned on. Everything is energized. The rotary function switch performs another function besides connecting and disconnecting battery power to the several components. It selects the particular type of calibrate signal to be used, and selects the appropriate monitoring channel. Thus, in position "5" the "pink" noise is selected as the calibrating signal although it began to function in position "4", it being only a filter on the output of the white noise generator.

*One acceptable choice of batteries is two 6.75 volt mercuries, Mallory TR-235R and 22.5 volt, Eveready 420.

The "white" noise generator and the "pink" noise filter shown in Figure 5 are commercial units manufactured by Allison Labs Division of Tracor, 6500 Tracor Lane, Austin, Texas 78721.* The small, 1600 ohm, 50 micro amper meter used in the model 3 was manufactured by International Instrument Company for Hughes Aircraft Company. The contract designation is AF/S/N: 0801-420-63-0251. They were obtained as surplus items.

Adjustments and Calibration:

Before the "calibrator" can be used it must itself be adjusted and calibrated. This requires an AC voltmeter that will read true RMS volts. To do this on "white" and "pink" noise the meter must have a high peak factor. Since the "calibrator" is at best no more accurate than the meter used to set it, great care should be taken to assure that such a meter is of high quality, and in good adjustment.

Procedure:

1. Join output pins 4 and 5 of P1 (shown in figure 5) through a convenient resistor of 50 to 100 ohms.

2. Set the rotary function switch to the "pink" noise position.

3. Connect the standard meter to be used for calibration to the "external monitor" P8 and P9, with P8 as the "Low" side.

4. Turn the level set control until the standard meter reads exactly 0.051 volts. This indicates that one milliamp RMS is flowing in the calibrate circuit.

5. Change the rotary function switch to "white" noise. Do Not change the Level Set Control. Adjust the white noise trimmer pot, R1, until the standard

*There is some evidence that later models of the Allison units may have a higher output than those for which this design was made. A resistor between the "PINK" filter and S5E-5, figure 32, should take care of this.

meter again reads exactly 0.051 volts.

6. Change the rotary function switch to "sine". Do <u>Not</u> change the level set control. Adjust the sine trimmer pot, R2, until the standard meter reads exactly 0.051 volts.

The standard meter reading should now remain unchanged as the rotary function switch is moved back and forth over the three positions. This situation <u>must</u> be attained before proceeding.

7. Set the function switch again to "pink" and with the standard meter still reading 0.051 volts, adjust the "meter set" pot, R6, until the meter of the "calibrator" reads exactly to the predetermined fiducial point. In Model 3 this is "4" on the meter scale (80% of full scale).

8. Next change the function switch to "white" noise, and adjust the white noise trim pot, R4, until the meter of the "calibrator" again reads exactly "4".

9. Move the function switch to "SIN", and adjust the sine trimpot, R5, until the "calibrator" meter again reads exactly "4".

Calibration is now complete. Remove the standard meter, close and secure the case.

<u>Operation</u>

The NUC ~~[illegible]~~ calibrator is battery-powered. To install batteries, open the case and insert two 6.75 volt mercury cells and <u>one</u> 22.5 volt dry battery as indicated, being careful to check the polarity. Under normal use conditions where the calibrator is turned on generally less than five minutes at a time, and used perhaps no more than a dozen times a week, the batteries should last for months. When changing batteries, be sure to remove any corrosion from the battery holder terminals, and <u>thoroughly</u> clean them. Be sure that installed batteries are secured firmly.

If calibration of the instrument has not been recently done, it may be advisable to do so before use. (See "Adjustments and Calibration"). When batteries have been installed, calibration completed if needed, and the case closed, plug the hydrophone cable to be used into P1, the 6 pin connector shown in figure 4, and connect P2, the 3 pin connector, to the GR 1558 analyzer or other device to be used.

When the hydrophone is submerged, signals can be received by energizing the pre-amplifier in the hydrophone case. This is accomplished by rotating the function switch on the "calibrator" from "off", extreme counter clockwise position, to "operate", position 2 clockwise. Power from the batteries in the analyzer arrives via pin 2 of P2; passes through S5A to P6; then through S2 to P5, and pin 3 of P1; and then down the cable to the hydrophone pre-amplifier (see Appendix A). Signals from the transducer arrive by way of pins 1 and 2 of P1, pass through monitoring points P3 and P4, to pins 3 and 1 of P2, and then on to some analyzer, and or recording device. The "calibrate" function is totally inoperative in this mode.

When calibration is to be performed, rotate the "function" switch to "white" noise, position 4 clockwise. Allow 60 seconds for "warm up". Calibrate signals are immediately available, but some small drift will occur during warm-up. To avoid any interruption of recording during this period, set the "internal - external" switch S1 to "external" before turning the function switch to "white" noise for warm-up. When ready for calibration, turn the rotary function switch to the calibration signal desired, "sine," "white," or "pink," and return S1 to "internal" position. Adjust the "level set" control

until the small panel meter on the face of the calibrator reads to the fiducial line ("4" on model 3). Make this setting as exactly as possible. There is t then as RMS current of one <u>milliamper</u> flowing through whatever calibrating arrangement has been built into the hydrophone - pre-amplifier assembly. When calibration is complete return the function switch to "operate," or "off" as required.

In practically all cases the level produced by the calibrate signal will be so much higher than the unknown signals that it may be injected "on top of" them without appreciably affecting the calibration results. If this were not true, some way of disconnecting the acoustic element of the hydrophone from the system during calibration would be necessary. Errors from this source are less than 0.4 dB if the calibrate level is more than 10 dB above the signal level.

This equipment has not been tested over a wide ambient temperature range, but has been tested under pressure of 300 lbs per square inch maintained for one hour. During this pressure test temperatures fell to about 35°F, and humidity was over 100%. In the laboratory the equipment has been operated at ambient temperatures as high as about 100°F. Changes in performance were negligible.

APPENDIX A

The General Radio type jack P6, and the switch S2 shown in figures 4 and 5 are not necessary for the calibration function, and may be omitted when the equipment is constructed. In this case, S5 would connect directly to P5. The inclusion of P6 and S2 makes available, when S2 is in the off position, of an unused conductor - for some other function. Also, by turning S2 off, a "system noise" measurement can be made. Hydrophone pre-amplifier voltage can be measured when the equipment is functioning by connecting a voltmeter between P4 and P5. The current can be measured by connecting a millimeter between P5 and P6, and setting S2 to "off." Signals from the hydrophone may be monitored by connecting between P3 and P4.

Appendix B

Three separate internal calibrate signals are selectable with the rotary function switch S5. These are 1000 hertz sine wave; "white" noise, spectrally flat; "pink" noise, with a minus 3 dB sprectrum slope. The "external calibrate" feature of this equipment permits the use of any kind of signal desired for calibration. The desired calibrate signal generator is connected to P7 and P8 (P8 "low"), figures 4 and 5, and the switch S1 is set to external. When using an external calibrate signal it will also be necessary to use an external monitoring meter between P8 and P9. The internal monitoring system is unique to the internal signals, offering a fiducial set point for them only. (See "description and construction").

APPENDIX C

Various arrangements have been devised for injecting calibration signals into a hydrophone pre-amplifier so, that for all practical purposes, they appear as though they were generated by the acoustic element of the hydrophone. One common way of doing this is to insert a small resistor (one to 100 ohms) in series with the acoustic transducer connection to the pre-amplifier. For example, if the resistor used was 10 ohms the calibrate signal developed by the model 3 would be one milliamp, times ten ohms, equals 10 millivolts. This is an electrical signal applied to the input of the preamp and affects the entire system above the transducer from some sound in the water.

By knowing the relation between a sound pressure in the water and the voltage generated by the transducer, one may by a reverse process infer what sound pressure in the water corresponds to the calibrate signal. This relation between sound pressure and voltage is the "sensitivity" of the transducer and must be known. Special facilities such as TRANSDEC at NUC are used to measure the sensitivities, and other parameters of hydrophones.

Sensitivity is usually expressed as a number of dB, referred to one volt as standard, that will be produced when the sound pressure in the water at the position of the hydrophone is one microbar. (A microbar equals one dyne per square centimeter.) Sensitivities vary from the minus seventies for some large types, to perhaps minus 110, or lower, for some very small types. One type that one might expect to be used with this equipment would be a 2 or 3 inch diameter cylinder, 5 to 10 inches long, and having a sensitivity of minus 80 dB re a volt per micro bar.

Perhaps the use of the calibrator can be better understood by an example. The setup might be as shown in figure 3. Suppose that a constant calibrate signal of 10 millivolts at the input of the hydrophone pre-amplifier produces a reading of 114 dB on the GR analyzer. And, suppose that some unknown sound from the sea produces a reading of 94 dB on the same GR meter. Since this is 20 dB lower than our calibration signal reading, the voltage at the input to the hydrophone preamp must have been 20 dB lower than the 10 mv of the calibration signal; i.e., one millivolt. The problem now is to determine what SPL (sound pressure level) in the water would produce this one millivolt. This can only be done if the hydrophone sensitivity is known. Assume a sensitivity of minus 80 dB re 1.0 volt per micro bar. Thus if the SPL is one microbar the transducer will produce 0.1 of a millivolt at the input to the pre-amp (0.1 millivolt equals -80 dB re 1.0 v.). If the SPL were 20 dB higher, i.e., 10 microbars, it would produce an input voltage of one (1.0) millivolt, which is just what the unknown signal was found to be doing. Therefore, the unknown sound source in the sea was producing a sound whose absolute sound pressure was plus 20 dB re a microbar at the location of the listening transducer. This is about the level of sound one might find at noisy locations in the sea.

Reference

Ref. 1 - M. A. Calderon and G. M. Wenz, "A Portable, General Purpose Underwater Sound Measuring System," Navy Undersea Warfare Center, TP25, Dec. 1967.

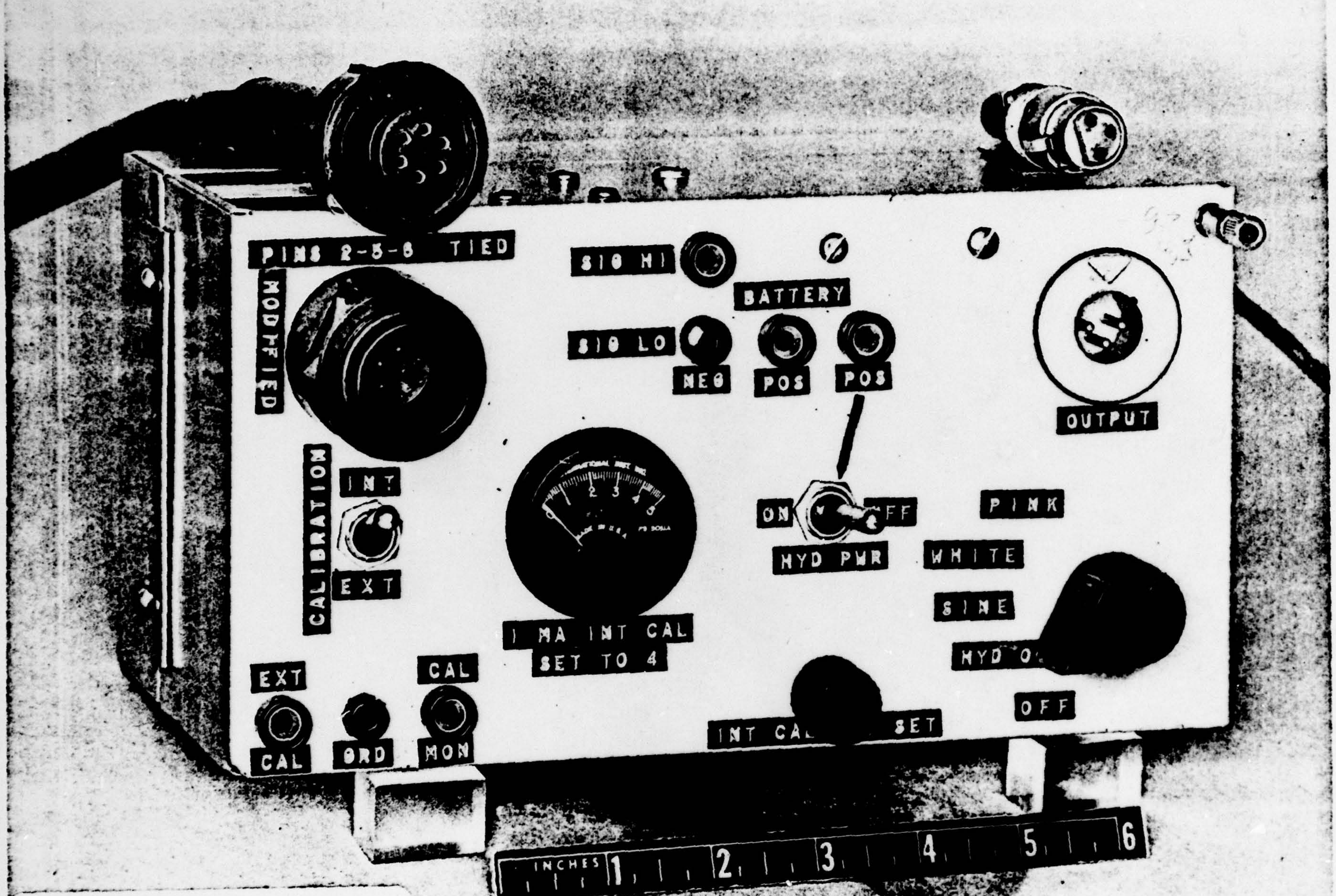

Fig. 1 - One example of a
"Calibrator Built by NUC.

Negative No. LSF -773-3-70

OFFICIAL U.S. NAVY PHOTOGRAPH
Naval Electronics Laboratory Center
~~Not for publication unless officially released~~

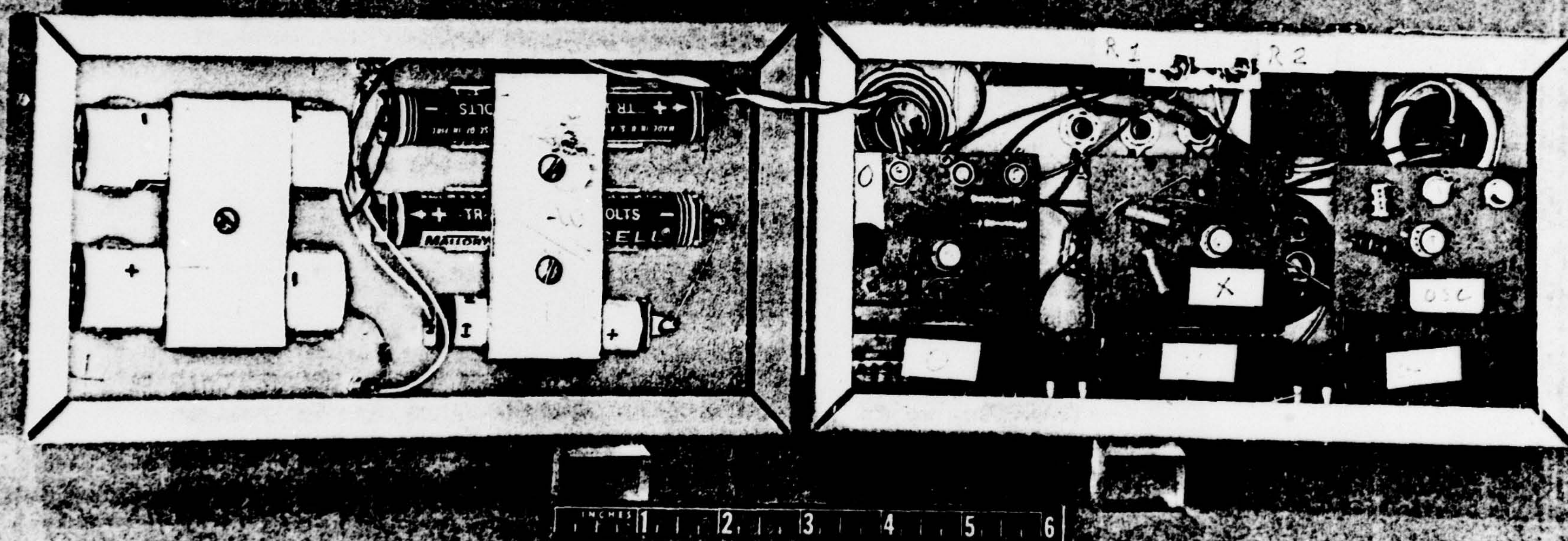

Fig. 2 - Interior View of NJC Calibrator

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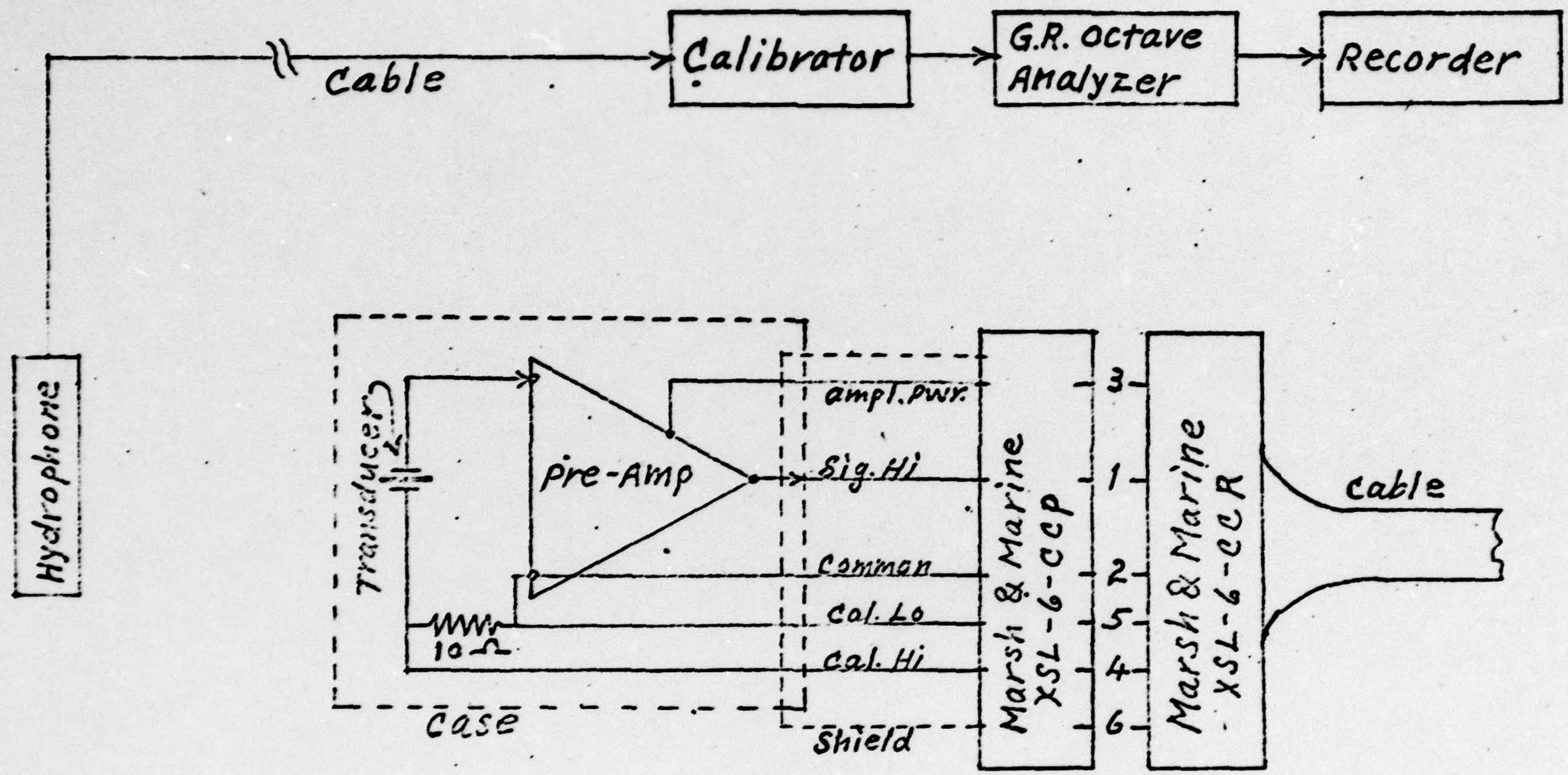
Fig. 3

Calibrator System Diagram



Hydrophone and Connector Details

Figure 3

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Fig. 4.

Control Panel. Functions for Sonar Calibrator Mod. 3

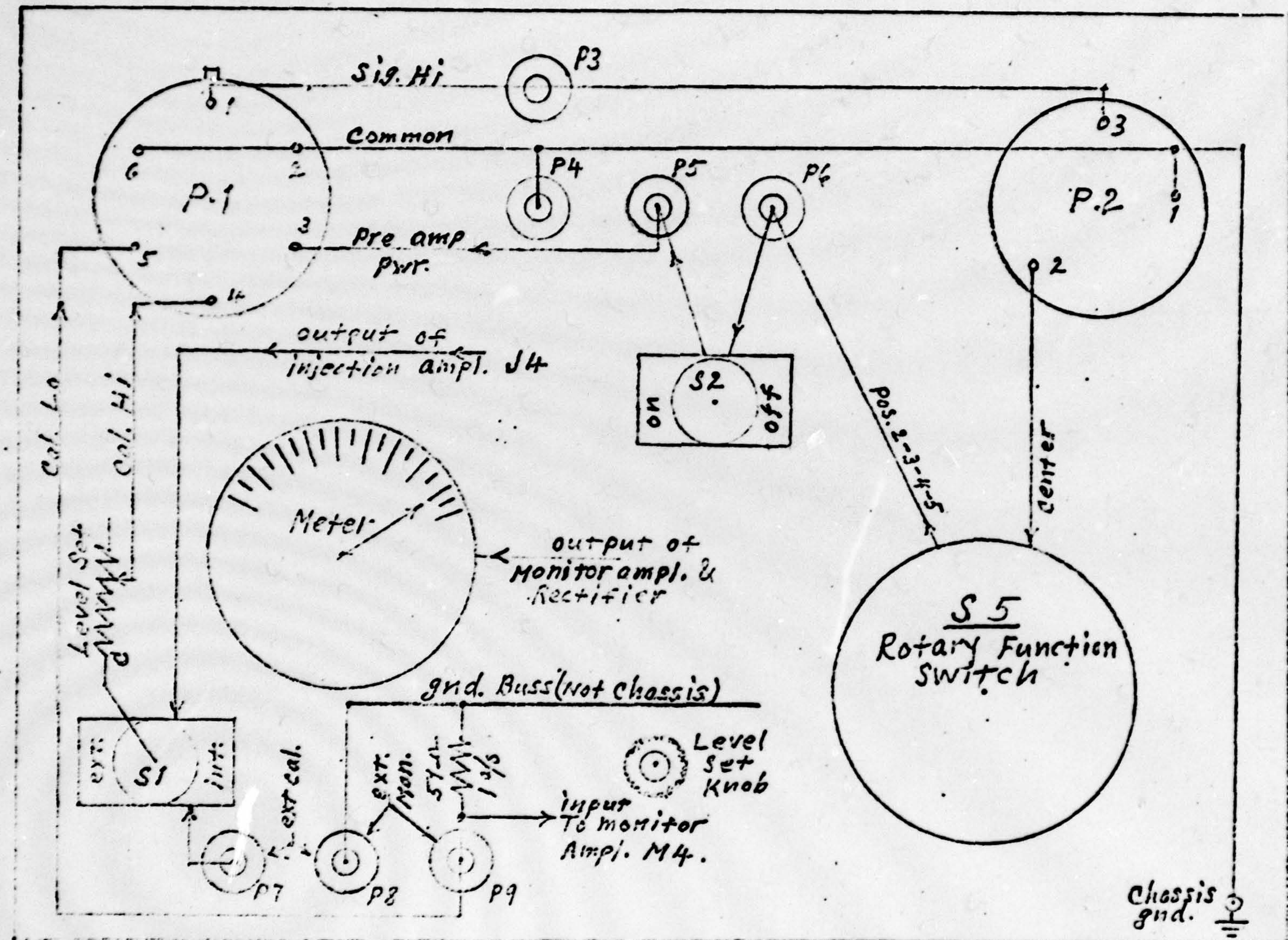

Figure 4

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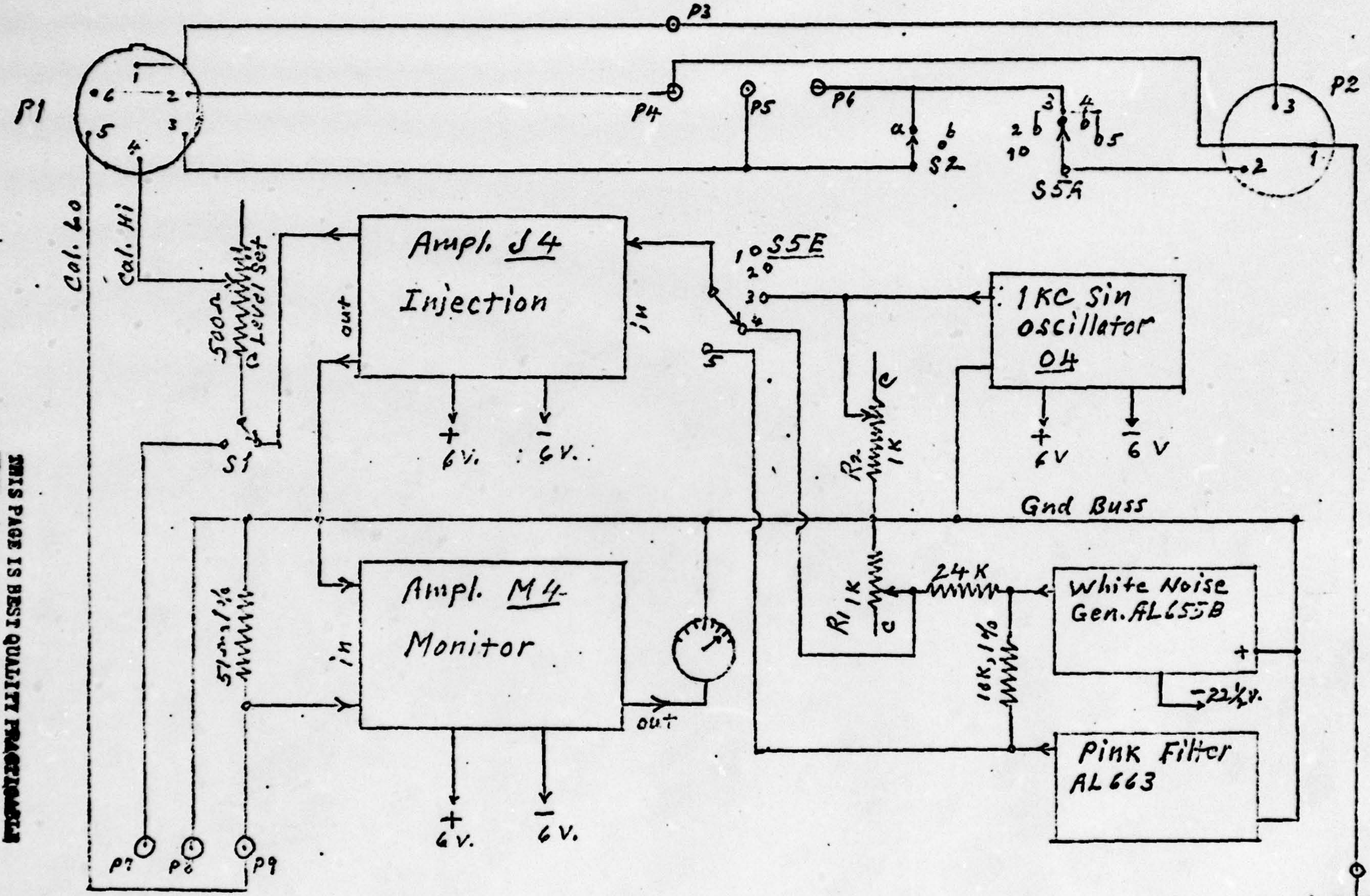
Fig. 5.

Sonar Calibrator Block Diagram - Mod 3.



Notes: Resistors R_1 & R_2 available from outside. Resistors Not specified are 1/10 W, 5%. P1 is Marsh & Marine XSL-6-BCR-P. P2 is 3-Pin Cannon.

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Figure 5

Monitoring Amplifier and Meter - Mod. 3

Fig. 6
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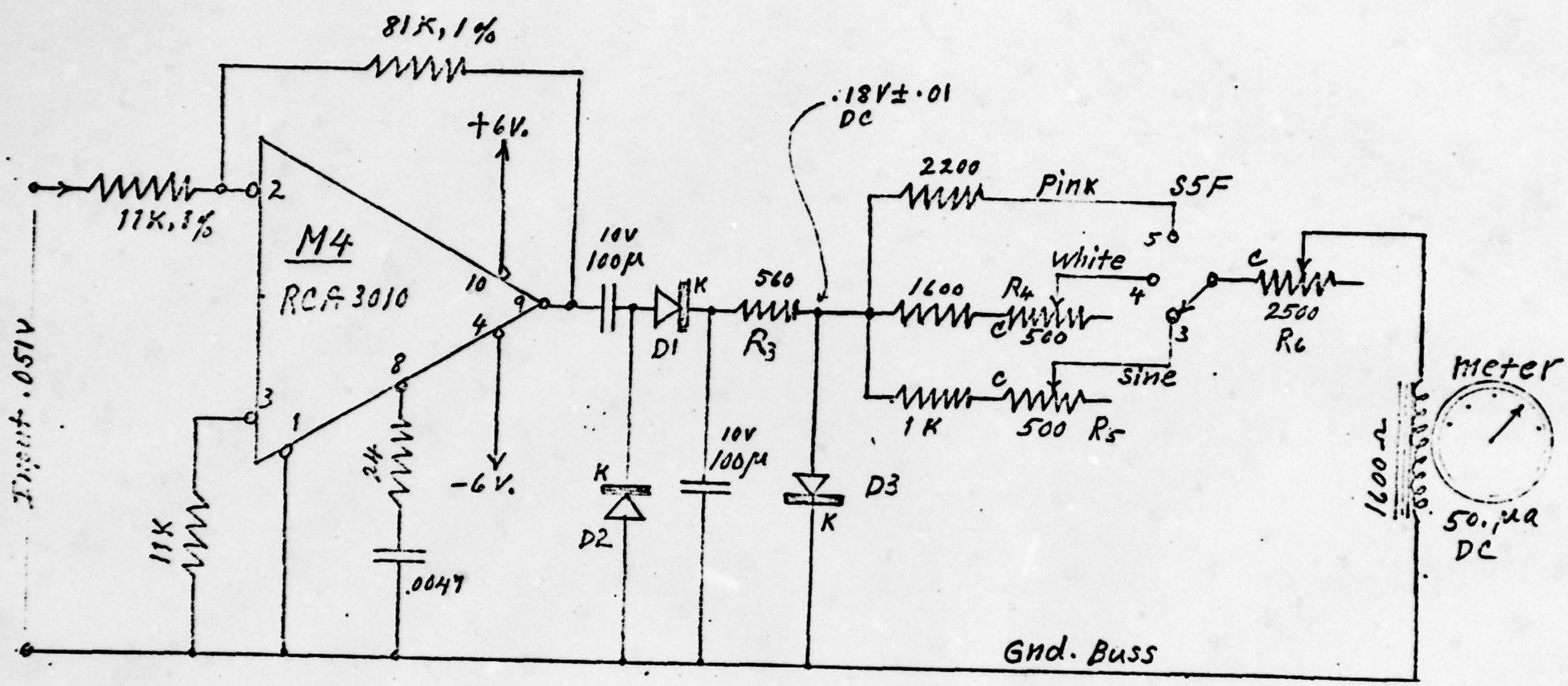


Notes. Diodes are 1N 277. Resistors, 5%, 1/10 w except as Noted.
For proper operation, adjustments should be made to insure that .18V. DC, as * Shown, is obtained for .051V, 1000 ~ Sine input. R_4, R_5 & R_6 to be available from outside.

* See text.

Figure 6

Fig. 7

Calibrate Signal Injection Amplifier - Mod 3.

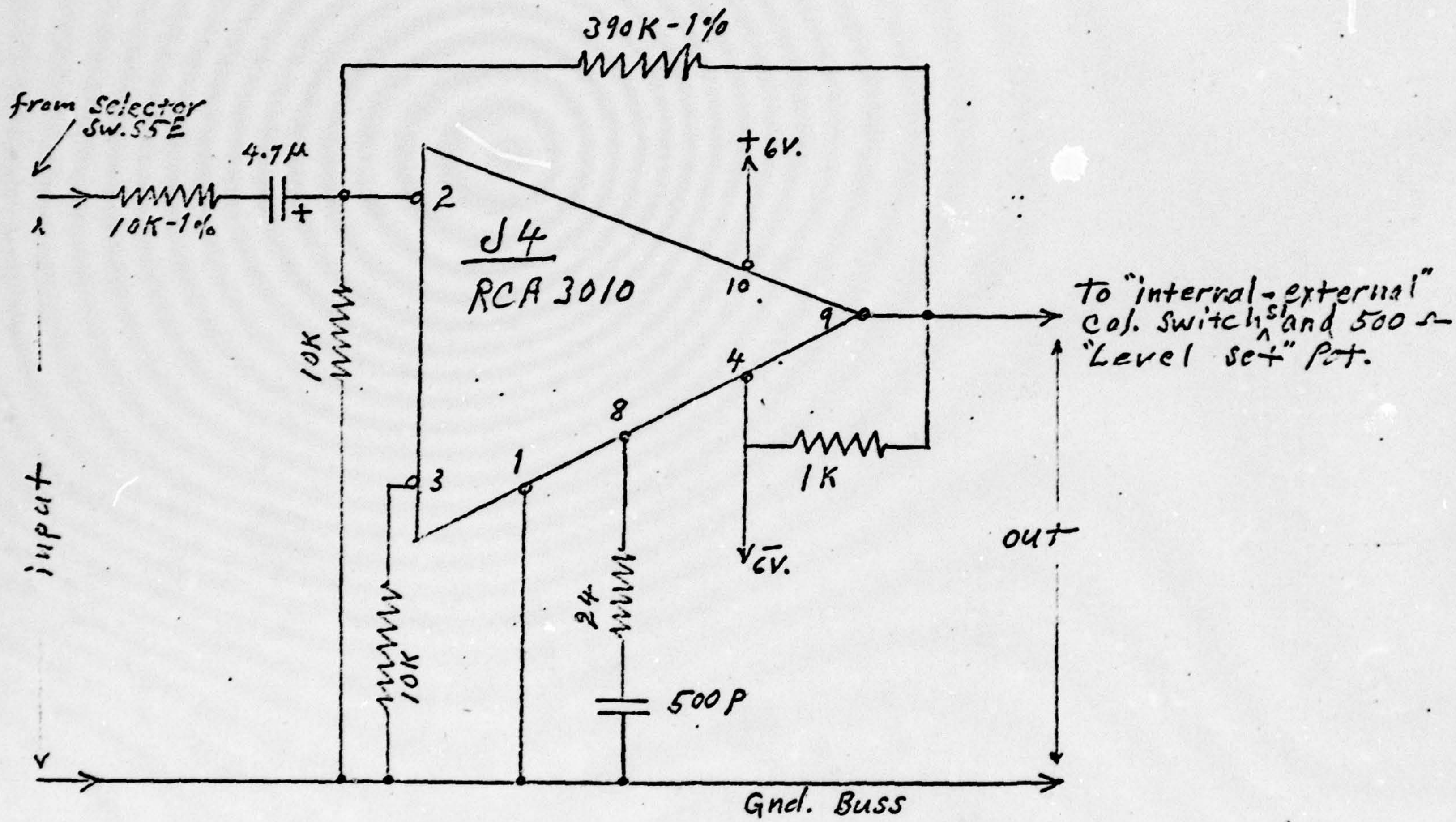
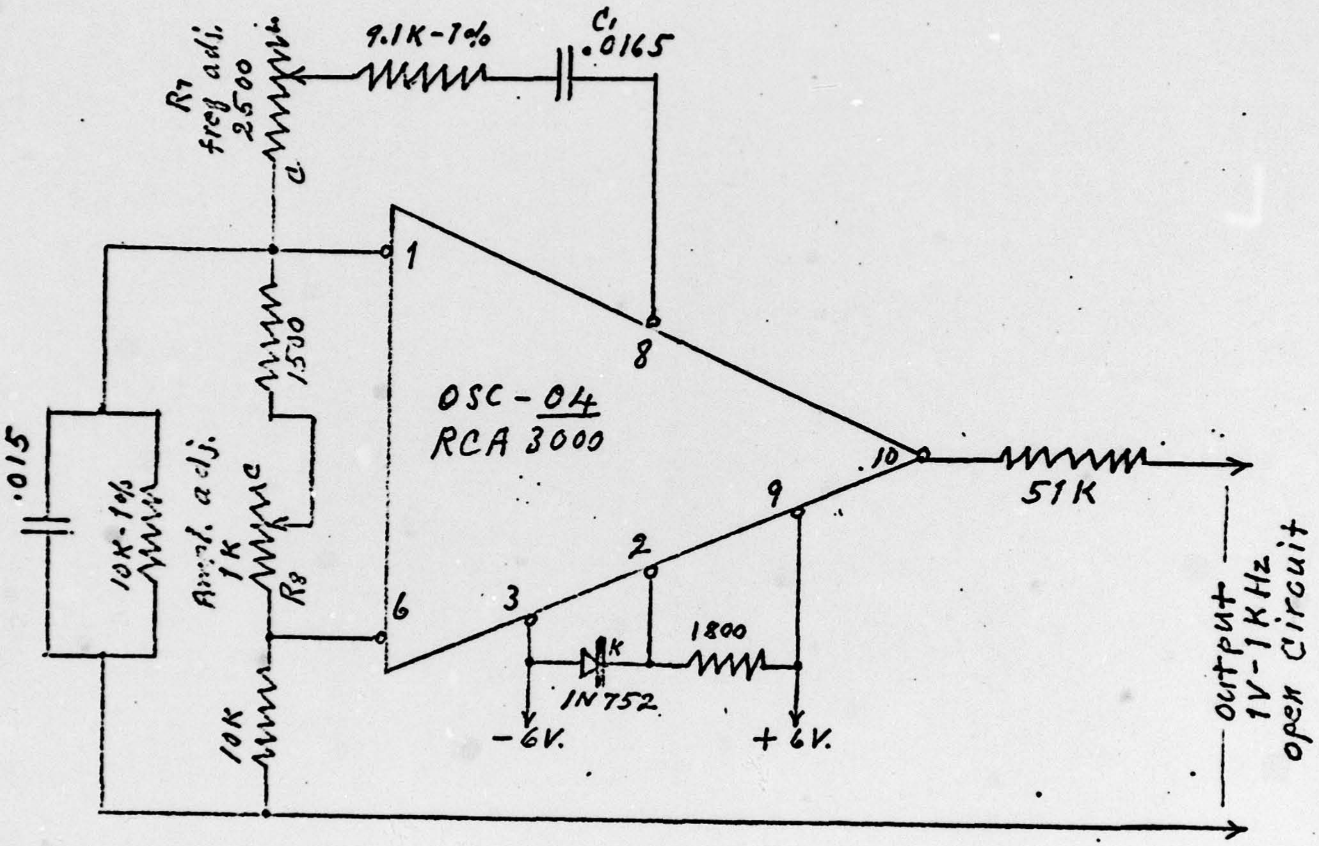


Figure 7

. All Resistors are 1/10 W, 5% except as noted. Keep all leads short & the

1KHz Sine Wave Oscillator - Mod. 3.



Note: Trim C_1 until freq. is 1KHz ± 5~ with the 2500 pot centered and appr. 1.0V. out (.02V. across 1KΩ). The two adjustment pots may be placed either so they are available from the outside or by removing the box cover, but leads must be extremely short.

Figure 8

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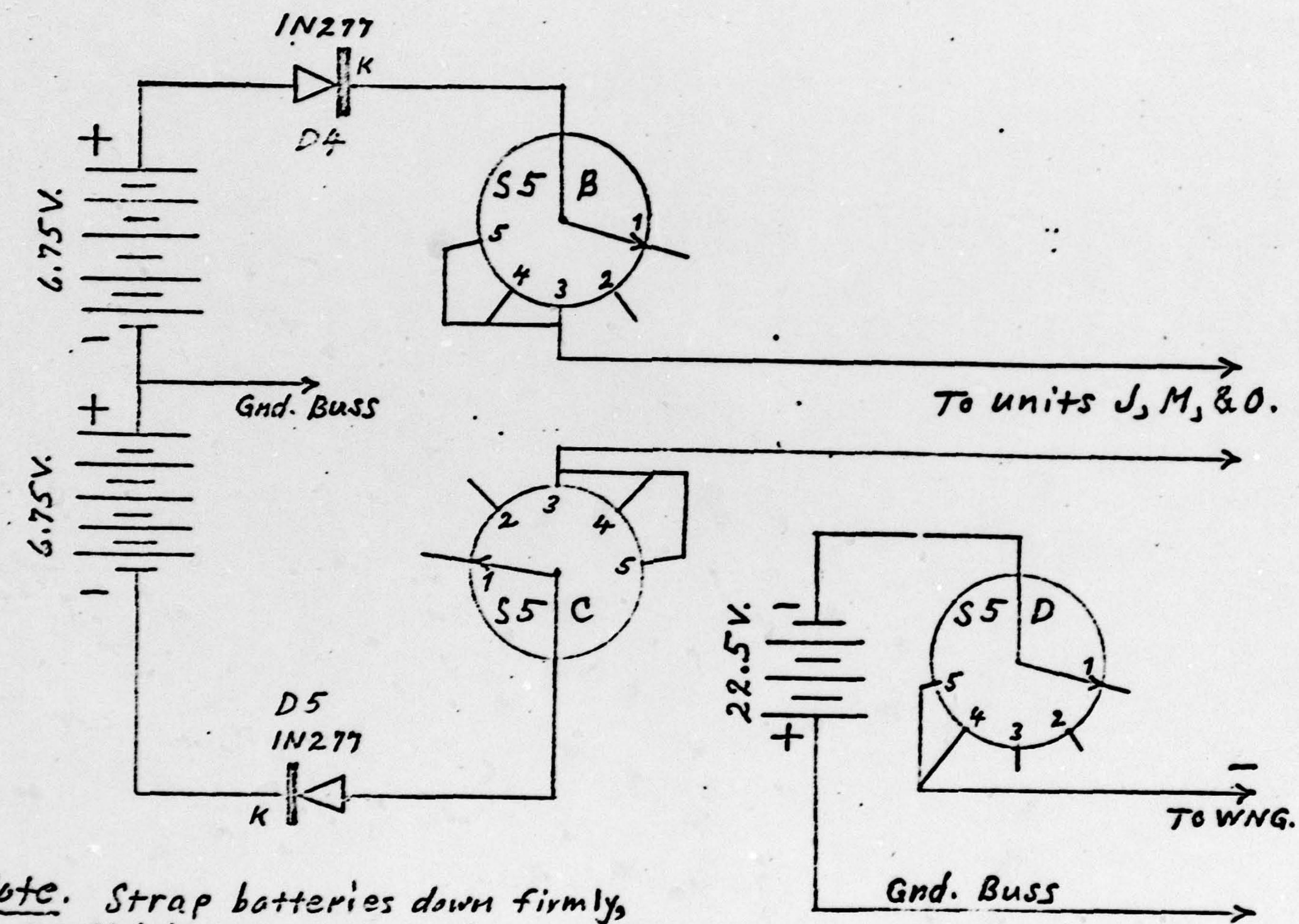
Fig. 9

Power Supply for Calibrator — Mod. 3.



Note. Strap batteries down firmly, and Plainly Mark the +, & − Connectors.

Figure 9

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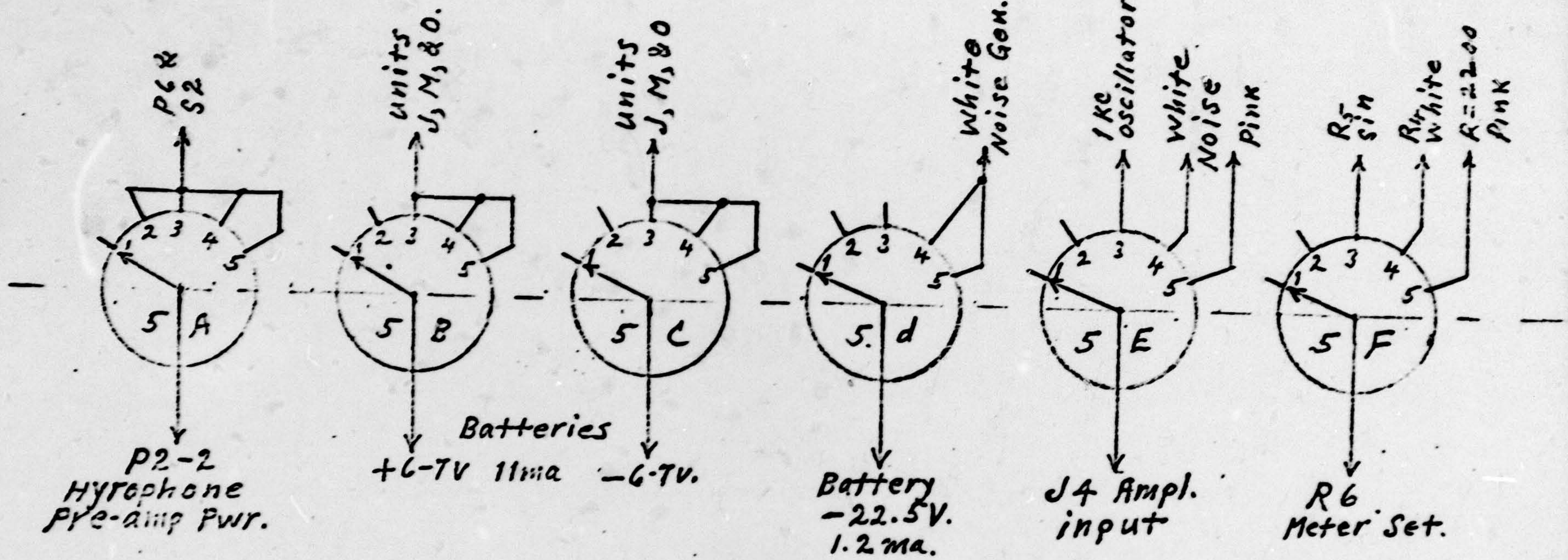
Fig. 10

Rotary Function Switch (S5) Connections - Mod. 3.



1. "Off" - Nothing functioning
2. Hydrophone "ON" here and in 3, 4, & 5.
3. Callibrator "ON" - 1 KHz Sine Source
4. " " "White" "
5. " " "Pink" "

Figure 10

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